Progress with convective parameterization for improved simulation of the MJO in the Community Earth System Model (CESM)

Richard Neale, Cecile Hannay, Dani Coleman and Jerry Olson

National Center for Atmospheric Research, Boulder, Colorado, USA

1. Recent Evolution in CCSM/CESM

The Community Atmosphere Model (CAM) component of the Community Earth System Model (CESM, formally CCSM) has undergone a significant transformation in recent years such that the dynamical core and physical parameterizations in version 5 (CAM5) have been completely updated from CAM3 (Table 1). In particular, additions and enhancements to the physical parameterizations of the boundary layer, shallow convection, microphysics, radiation and aerosol schemes (Fig 1.) have been made. In addition to the new classes of scientific problems that are now possible (e.g., the aerosol indirect effect) it is important to maintain and improve the representation of tropical variability and in particular the MJO. Figure 2 shows the evolution of the MJO from CAM3 through to CAM4. It shows significant improvements in MJO strength in model simulations beyond CAM3 due to the deep convection modifications introduced in CAM3.5. There are still remaining issues with the representation of the amplitude in particular. Activity to assess and improve the fidelity of the MJO through the use of testbed tools and parameterization sensitivity tests is ongoing and examples are shown below.

Model	CCSM3 *(2004)*	CCSM3.5 *(2007)*	CCSM4 *(Apr 2010)*	CESM1 *(Jun 2010)*
Atmosphere	CAM3 (L26)	CAM3.5 (L26)	CAM4 (L26)	CAM5 (L30)
Boundary Layer	Holtslag and Boville (93)	Holtslag and Boville	Holtslag and Boville	UW *Diagnostic TKE* Park et al. (09)
Shallow Convection	Hack (94)	Hack	Hack	UW *TKE/CIN* Park et al. (09)
Deep Convection	Zhang and McFarlane (95)	Zhang and McFarlane Neale et al.(08), Richter and Rasch (08) mods.	Zhang and McFarlane Neale et al., Richter and Rasch mods.	Zhang and McFarlane Neale et al., Richter and Rasch mods.
Stratiform Cloud	Rasch and Kristjansson (98) *Single Moment*	Rasch and K. *Single Moment*	Rasch and K. *Single Moment*	Morrison and Gettelman (08) *Double Moment* Park Macrophysics Park et al. (10)
Radiation	CAMRT (01)	CAMRT	CAMRT	RRTMG Iacono et al. (2008)
Aerosols	Bulk Aerosol Model (BAM)	BAM	BAM	Modal Aerosol Model (MAM) Ghan et al. (2010)
Dynamics	Spectral	Finite Volume (96,04)	Finite Volume HOMME	Finite Volume HOMME
Ocean	POP2 (L40)	POP2.1 (L60)	POP2.2	POP2.2 – *BGC*
Land	CLM3	CLM3.5	CLM4 – *CN*	CLM4
Sea Ice	CSIM4	CSIM4	CICE	CICE

Table 1. The evolution of CAM from version 3 through version 5. All models available on the CCSM/CESM release website (http://www.ccsm.ucar.edu/) from June 21st 2010.

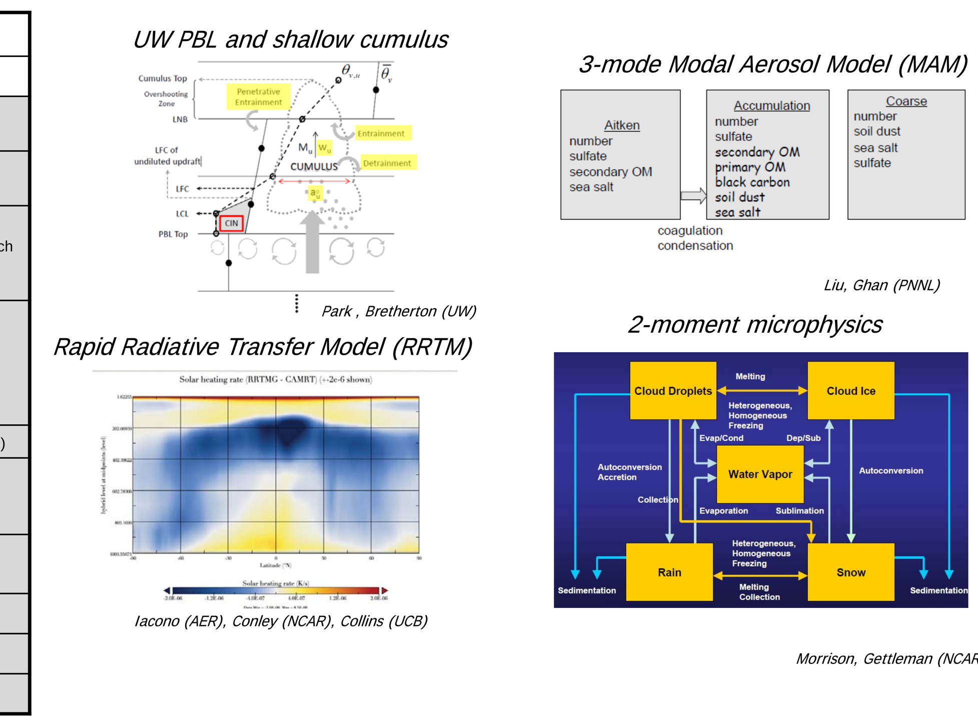

Figure 1. Major physics parameterization changes from CAM4 to CAM5

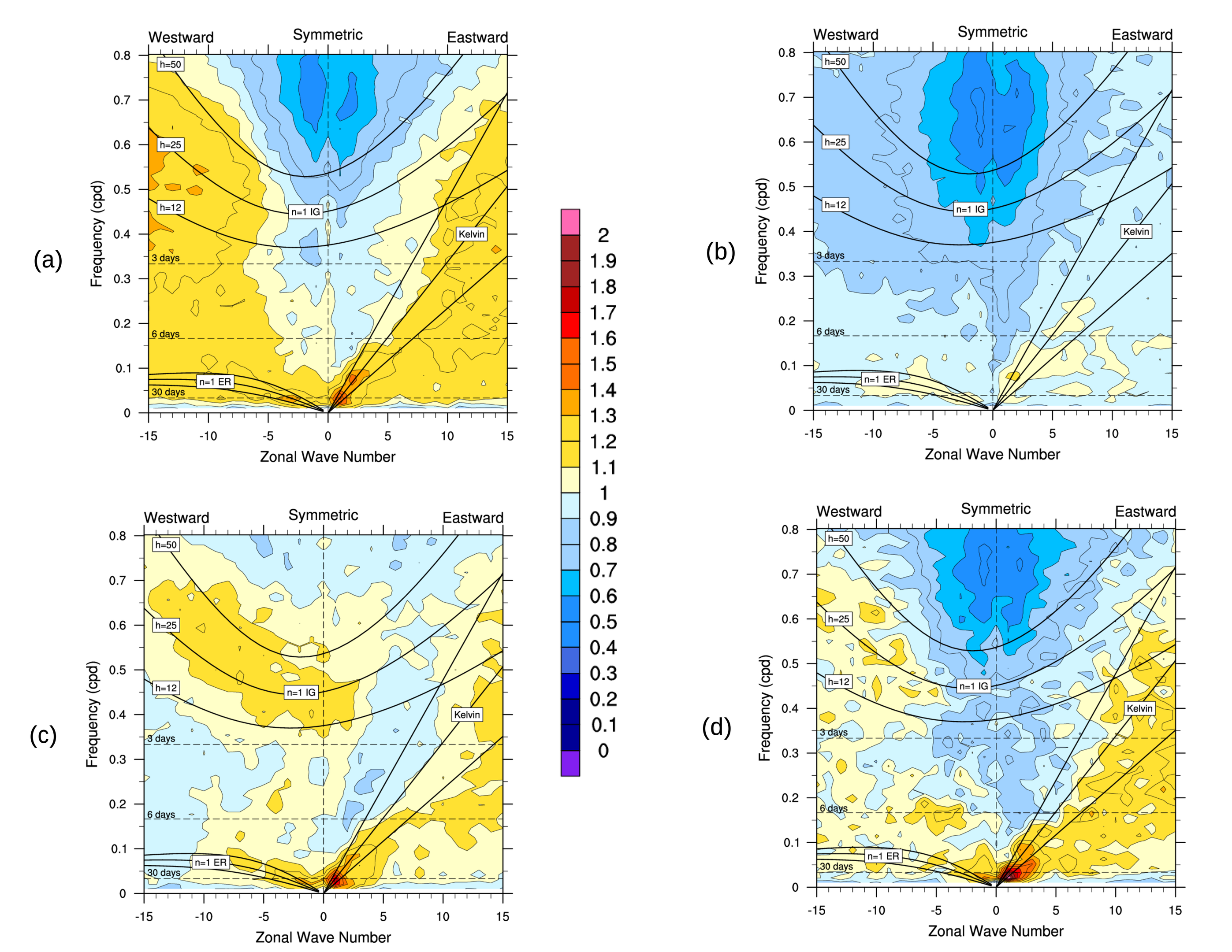

Figure 2. The scaled change in tropical wavenumber frequency power of the 850-mb zonal wind associated with the addition of deep convection changes in CAM3.5. Increases to the power are >1 decreases are < 1. (a) including convective dilution into CAM; (b) including convective momentum transports (CMT) in CAM; (c) including dilution and CMT in CAM; (d) including dilution and CMT in fully coupled CCSM.

2. The MJO in a Cloud-Associated Parameterization Testbed (CAPT)

The CCPP-ARM CAPT project (Philips et al., 2004) is an efficient method for assessing the evolution of systematic errors in climate models. It employs a technique similar to traditional weather forecasting, whereby a series of short global forecasts (in this case each 5 days) are performed after being initialized with reanalyses fields (in this case ERA-Interim). Only small adjustments are made to fit the host model configuration and no data assimilation is performed. An ensemble of forecasts are then available at various lead times and can be analyzed for the evolution of systematic error (Fig. 3). Figure 4 shows such a set of 5-day forecasts for the whole of summer 2008, for CAM3, CAM4 and CAM5 at a 2-degree resolution and with 26-30 vertical levels. There is significant propagating MJO activity as measured by the 200-mb velocity potential anomalies in the analysis (day 0). In CAM3 although the strength of the signal is retained the propagating aspects begin to be lost at day 1 and are completely lost by day 5. CAM4 and CAM5 improve significantly on this and the propagating signal is retain out to the 5-day lead time. Similarly for precipitation, CAM3 loses the strength of the mid-July precipitation signal very rapidly along with any indications of the observed propagation. CAM4 and CAM5 retain the strength of the precipitation anomalies at least through day 3 along with some eastward propagation.

Ensemble mean forecast and timeseries forecast

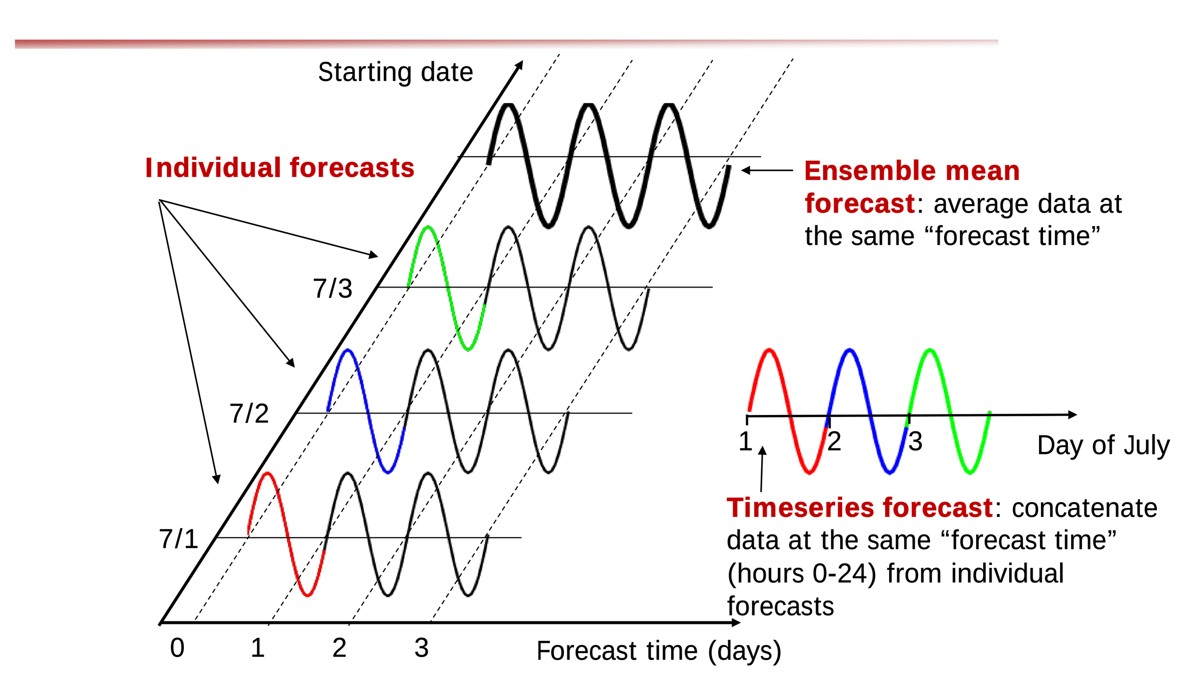

Figure 3. Schematic of the series of forecasts produced by the CAPT technique.

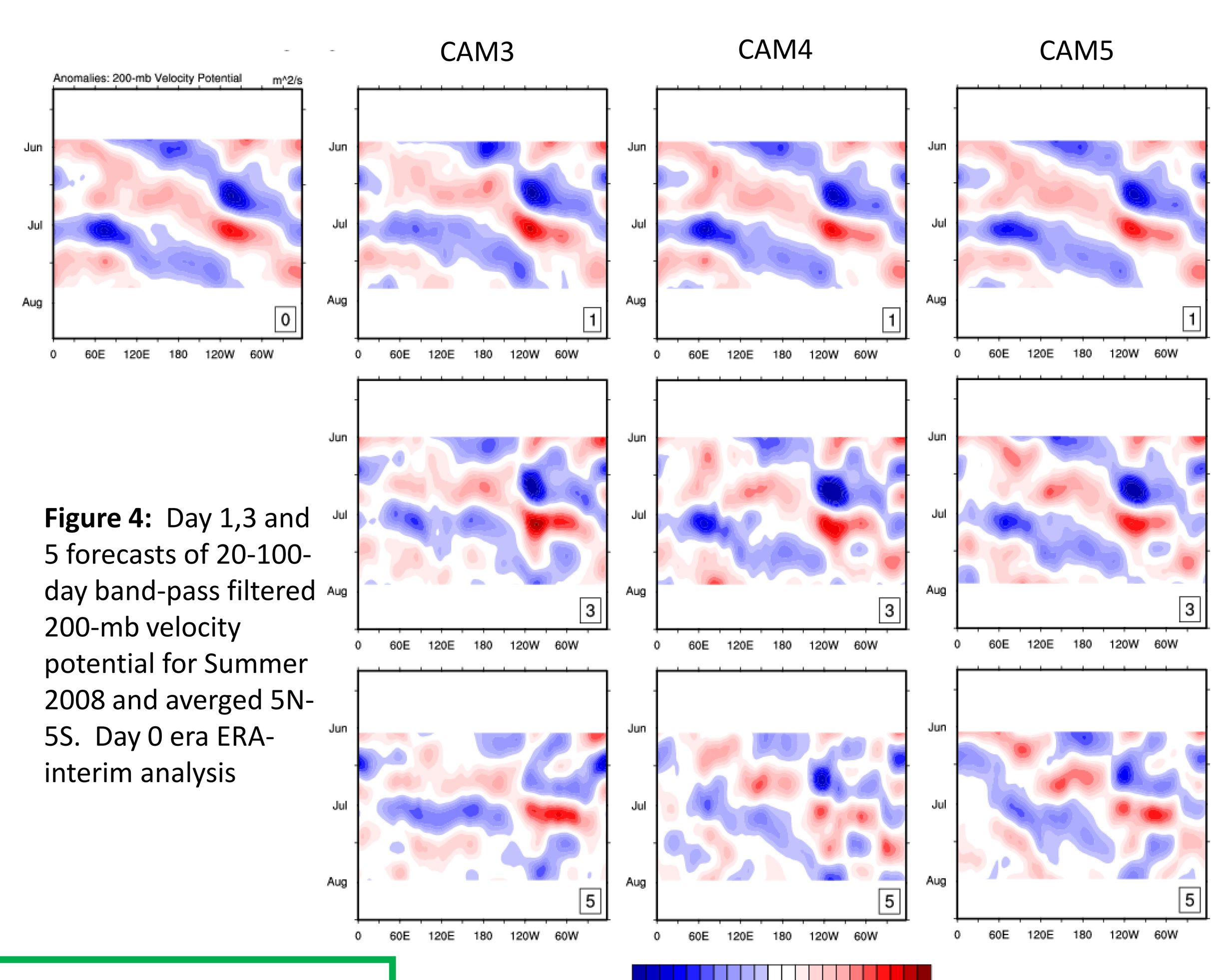

Figure 4: Day 1,3 and 5 forecasts of 20-100-day band-pass filtered 200-mb velocity potential for Summer 2008 and averaged 5N-5S. Day 0 era ERA-interim analysis

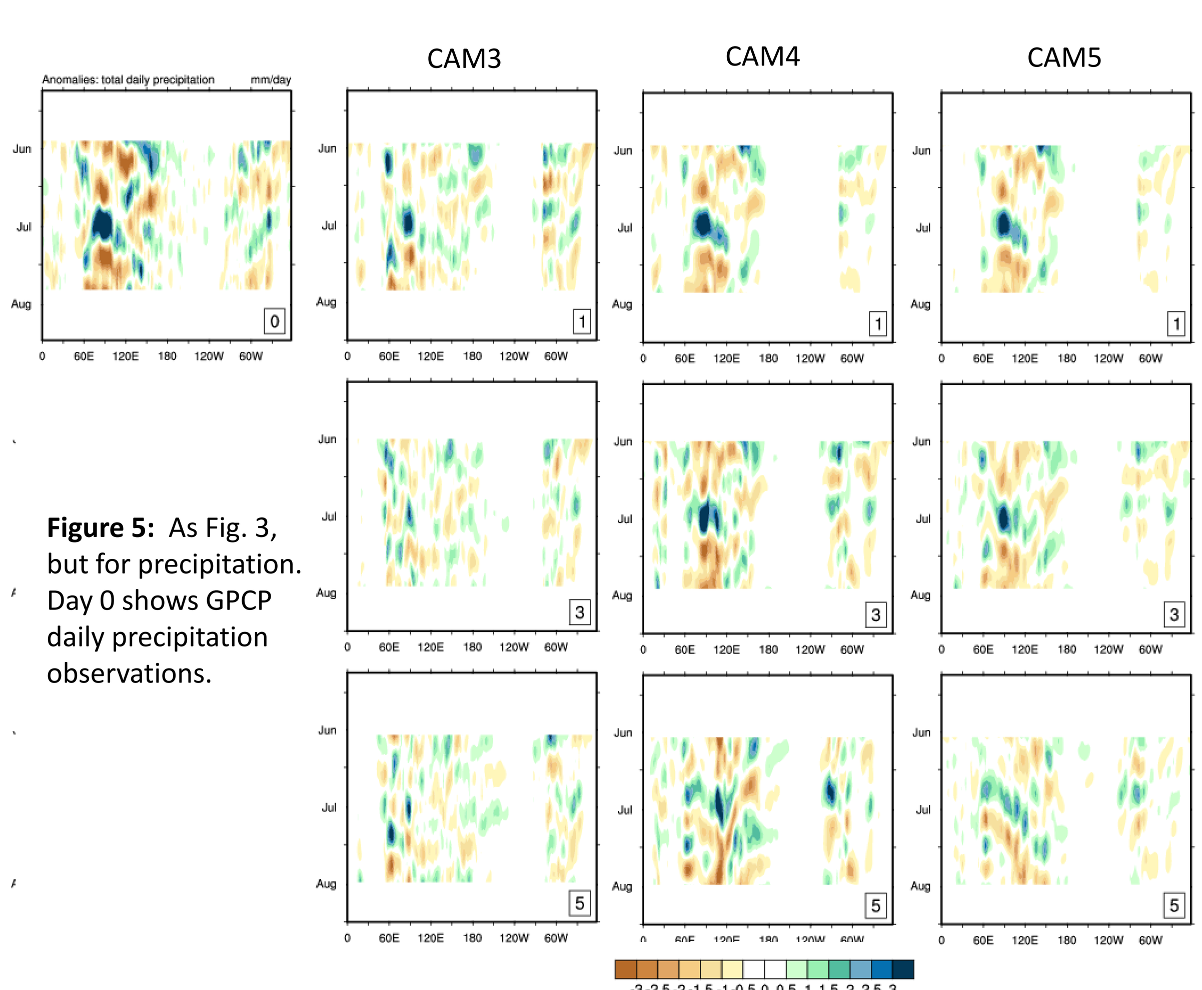

Figure 5: As Fig. 3, but for precipitation. Day 0 shows GPCP daily precipitation observations.

3. A Simple Parameterization of Convective Organization

Associated with the relative improvements in the MJO simulation beyond CAM3 were improvements in the PDF of high frequency tropical precipitation rates . Attempting to mimic this effect, a parameterization of convective organization has been tested based on Mapes and Neale (2010). Organization is represented as a single 2D prognostic variable in the model (org) where;

$$\frac{\partial(org)}{\partial t} = \alpha E_P - (org)/\tau$$

E_p is the evaporation of convective precipitation, τ is a decay timescale of 3 hours and α is a disposable constant. *Org* is then applied as a scaling factor to the strength of deep convection cloud base mass flux in CAM. This has the impact of biasing the PDF towards more frequent strong precipitation events in agreement with observations (Fig. 6). Focusing on the control and '*org with advection by surface winds*' (Fig. 7) shows a significant improvement to the coherent eastward propagation, particularly with the dynamical organization. In addition, the latitudinal propagation which was completely absent in the control is much more apparant, but with a faster than observed phase speed. Research examining the relationship between precipitation statistics and tropical wave activity is ongoing.

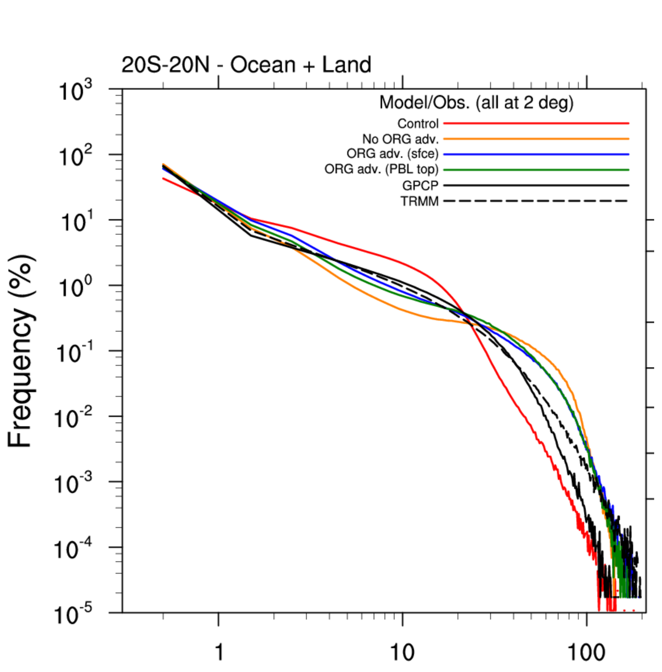

Figure 6. Daily mean tropical precipitation PDF for the control (red), with org implementation (orange), with org + advection by surface winds (blue), with org + advection by winds at top of the PBL (green) and observed (black)

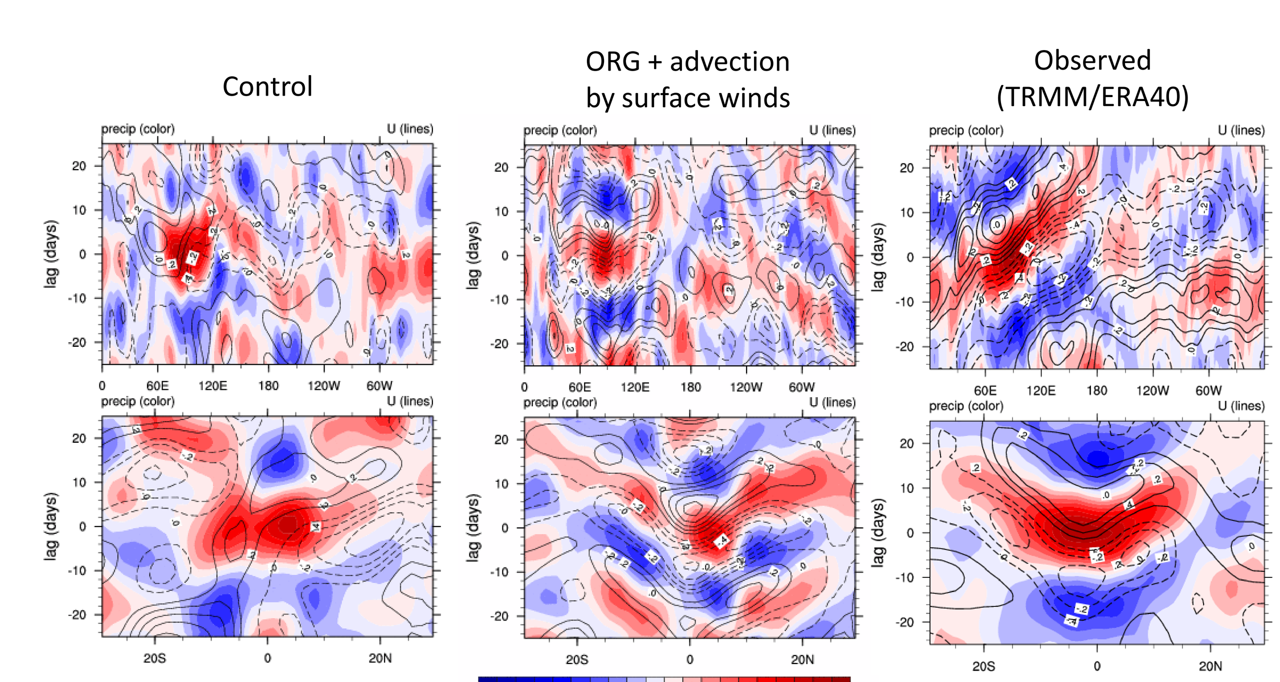

Figure 7. Lag-correlation of 20-100 day band-pass filtered rainfall (color) and 850-mb zonal wind (lines) for poleward Bay of Bengal propagation (bottom) and equatorial (5S-5N) zonal propagation (bottom).

References

Mapes, B. E. and Neale, R. B., (2010) Parameterizing Convective Organization. *JAMES,* **submitted**

Philips, T. J., et. al, (2004) Evaluating Parameterizations in general Circulation Models: Climate Simulation Meets Weather Prediction. *Bull. Amer. Meteor. Soc.,* **85,** 1903-1915

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